

The University of Chicago

A STUDY OF THE GEOLOGY AND
ORE DEPOSITS OF THE ASHBROOK
SILVER MINING DISTRICT, UTAH

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
PHYSICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY

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By

VICTOR E. PETERSON

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A STUDY OF THE GEOLOGY AND ORE DEPOSITS OF THE ASHBROOK SILVER MINING DISTRICT, UTAH.¹

VICTOR E. PETERSON.

ABSTRACT.

The ore of the Ashbrook district occurs as irregular patchy replacement deposits in fractured and folded limestone, whose structure has strongly influenced distribution of the orebodies. The distribution is controlled by small crenulations within the limestone, the apical portions of which are usually marked by a strong development of secondary calcite, which is generally more susceptible to replacement by mineralizing solutions. Due to two episodes of minor fracturing, the sequence of primary mineralization can be divided into three periods of deposition: (1) rhodochrosite to the exclusion of other minerals, (2) quartz, pyrite, arsenopyrite, sphalerite, and minor amounts of chalcopyrite, and (3) galena, argyrodite, pyrargyrite, pearceite, tennantite, and an unidentified mineral. The second phase seems to be responsible for the minor gold values in the ores. Processes of enrichment and oxidation have produced a large group of secondary minerals. Alteration of the primary silver minerals has been mainly to argentite and native silver which together account for the main values found in the ores.

THE Ashbrook district, one of the oldest mining districts in Utah, has at times attained a very high-ranking position in the State's total silver production. Information regarding the nature of the geology and ore deposits is very limited in the literature and it is hoped that the present paper will add to the knowledge of this area.

The district is situated in the extreme northwestern corner of Boxelder County, approximately 10 miles east of the Nevada State line and 1 mile south of the Idaho State line, and comprises 71 claims and at least 7 mines which have at one time or another been of considerable local interest. In all, there have been ap-

¹ The material presented here is taken from the writer's doctor's dissertation on file at the University of Chicago.

proximately 5 miles of development work completed, of which more than 90 per cent is accounted for in one mine.

GENERAL GEOLOGY.

Physiography. The district is situated high on the west side of the Goose Creek Range, approximately within the area where this range merges with a northwestward extension of the Grouse Creek Range on the east. The topography of the district, similar to that of the higher reaches of many ranges in this part of the Great Basin, consists of high, smooth, east-west transverse ridges of nearly equal elevation, separated by broad, roughly V-shaped valleys, which descend gently from the high, northward-trending crest of the range. The total relief in the district is nearly 2,000 feet, and the higher points attain elevations of about 8,000 feet. Probably the most outstanding features of the topography in the area are the marked accordances in elevation and slope of the principal east-west ridges, and their accordance in elevation with the many local flattened areas. This condition prevails over a large part of the western slopes of the Goose Creek Range in Utah. Conclusive evidence indicates that this striking accordances is an expression of a once continuous erosion surface which correlates closely in time with the Snowdrift peneplain defined by Mansfield² in southeastern Idaho. A similar erosion surface has been recognized by Anderson³ in eastern Cassia County, Idaho, approximately 20 miles northeast of this district. The east-west valleys cutting this old erosion surface appear to owe their origin primarily to a period of erosion closely corresponding to that responsible for the Tygee erosion surface in southeastern Idaho, also defined by Mansfield.⁴ The chief evidence for these conclusions is the relationship which exists between the local topography and the Salt Lake formation, which is known to be deposited on the Tygee erosion surface in southeastern Idaho.

² Mansfield, G. R.: *Geology and mineral resources of part of southeastern Idaho*. U. S. Geol. Surv., Prof. Pap. 152: 8, 11, 1927.

³ Anderson, A. L.: *Geology and mineral resources of eastern Cassia county, Idaho*. Idaho Bur. Mines and Geol. Bull. 14: 9, 1931.

⁴ Mansfield, G. R.: *op. cit.*, p. 15.

Structural Geology. The most prominent structure within the district is a broad, spoon-like syncline which plunges at a low angle to the south. Except for the complicated structures within the pre-Cambrian rocks, all other major structural features in the district are superimposed on this structure. The district is

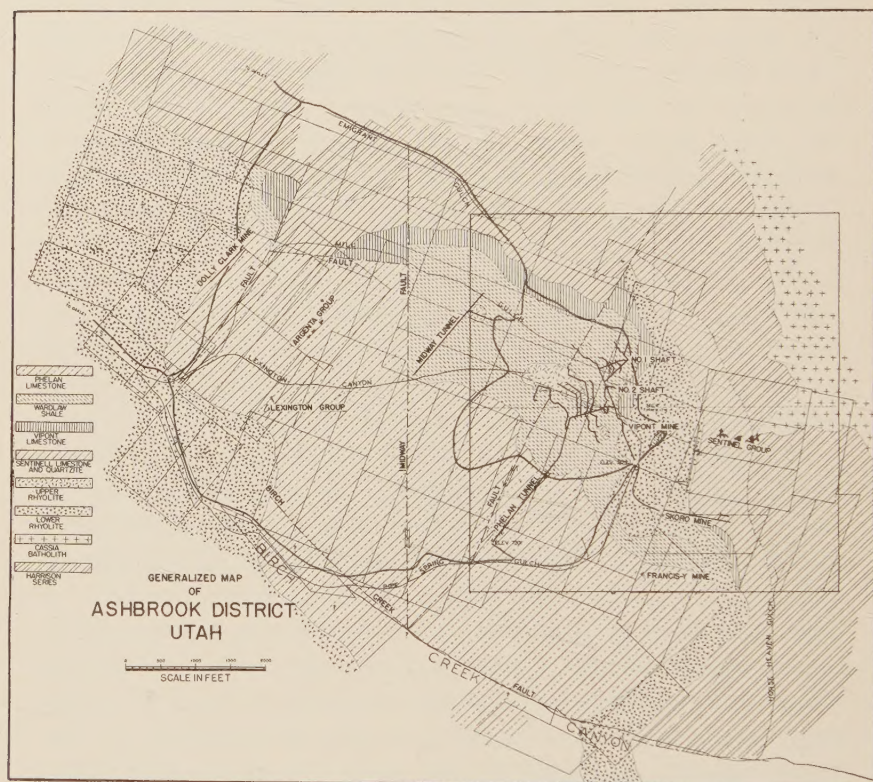


FIG. 1. The Ashbrook District, Utah.

situated in the north end of this fold (Fig. 1). The length of the fold is not known, though it is apparent that it extends several miles beyond the southern limits of the district. Prior to extensive displacement by north-south and east-west normal faults, the fold appears to have been approximately symmetrical with the steepest dips on the flanks about 20 degrees. The fold is not

simple, but is complicated by the presence of numerous major and minor crenulations, the largest of which have a roughly radial relation with respect to the major fold. These crenulations have played a very important part in the localization and distribution of the ore deposits of the district. Further complications in the general outline of the fold have been introduced by the warping associated with two periods of magmatic intrusion.

Though on a large scale, faulting within the district is not complicated and is confined mainly to several large normal faults. These faults may have played an important part in the distribution of the intrusives associated with the ore deposits, but no evidence was observed that would indicate that they directly influenced the distribution of the deposits themselves. The faults all appear to belong to approximately the same period of deformation and antedate both the late intrusives and the ore deposits. It is assumed from physiographic evidence, from which the age of the late intrusives can be roughly estimated, that these faults belong to a period of deformation closely following the Laramide revolution, when compressive forces had ceased, and tensional forces prevailed. It is clear that these faults are much older than the late "Basin-Range" faulting. Faults of similar age have been described by Anderson ⁵ in eastern Cassia County, Idaho, and are attributed to deformation closely following the Laramide revolution. The formation of the major fold of the district appears to have been concurrent with Laramide disturbances.

Stratigraphy. Within or in the immediate vicinity of the district there are rocks ranging from pre-Cambrian to late Tertiary. They include a series of metamorphosed pre-Cambrian schists, slates, and gneisses with beds of marble and quartzite, overlain by Paleozoic limestones and shale. The lower part of the series, including the Paleozoic rocks, has been intruded by a large granite batholith and its associated pegmatites, which Anderson ⁶ considers to be of late Cretaceous or early Eocene age. Rhyolite porphyries intrude the upper part of the series in a sill-

⁵ Anderson, A. L.: *op. cit.*, pp. 78 and 87.

⁶ *Ibid.*, p. 55.

like fashion. These later intrusives appear to belong to an earlier period of volcanic activity than the quartz latites of eastern Cassia County, Idaho, possibly the late Eocene or early Oligocene. The Salt Lake formation of late Tertiary age (Pliocene?) crops out just off the western edge of the district.

Definition of the recognized local stratigraphic units is difficult, due to their remoteness from described stratigraphic sections and the scarcity of fossils in the Paleozoic rocks. Correlation was made here entirely on lithologic similarities between the local series and defined stratigraphic units within the surrounding region.

Pre-Cambrian. The pre-Cambrian rocks of the district are equivalent to part of the great thickness of contorted and metamorphosed rocks which Anderson ⁷ has described in eastern Cassia County, Idaho, and named the Harrison series from their occurrence at Harrison Peak in the Albion Range. It is not known how much nor which member or members of this three-fold series, are represented in the Ashbrook district. The lithology of the local series most closely resembles parts of the middle and upper divisions.

Paleozoic. The Paleozoic rocks of the district are divided into five separate lithologic units, the general features of which are outlined in Table 1. The lithology of the two lowest members of this series closely resembles rocks of Cambrian age in the Raft River Range, approximately 30 miles east of the district. The lowest quartzite member closely resembles parts of the Brigham quartzite in eastern Boxelder County, and they are tentatively correlated. The Sentinell limestone is the host rock for the deposits of the Skoro and Sentinell mines.

In eastern Cassia County, Idaho, Anderson ⁸ has described a series of rocks of Carboniferous age which are very similar to the three highest members of the local Paleozoic series, and it is tentatively considered that the two series are correlatives. The two highest limestone members of the local Paleozoic series make

⁷ *Ibid.*, pp. 24-27.

⁸ *Ibid.*, p. 31.

up the host rocks for the ore deposits of the Vipont and old Lexington-Argenta mines.

Igneous Rocks. The igneous rocks of the district can be divided into two groups, the granites and pegmatites of the Cassia batholith, and the later rhyolite porphyries. Since it was apparent during the investigation that the first of these groups has

TABLE 1.
GENERALIZED STRATIGRAPHIC SECTION OF ASHBROOK DISTRICT.

Age.		Formation.	Thickness.	General Lithologic Character.
Paleozoics	Carboniferous (?)	Phelan limestone	1,000–1,500	Coarse to finely crystalline, light blue-gray, massive bedded limestone, locally cherty.
		Wardlaw shale	400	Black to gray, thin to massive bedded, pyritic shale, locally containing lenses of gray dolomitic limestone.
		Vipont limestone	50–100	Fine-grained, crystalline, blue-gray limestone, locally containing numerous small calcite stringers.
	Cambrian (?)	Sentinell limestone	50–100	Light gray, medium grained, crystalline, thin-bedded limestone, usually broken and containing numerous calcite stringers.
		Sentinell quartzite	100–100	White to tan, sucrose quartzite.
Pre-Cambrian	Harrison Series	Upper?	300–400 500–1,000	Usually light gray, contorted and fractured limestone and marble. Massive, white to pinkish, somewhat schistose, vitreous quartzite.
		Middle?	400–600	Fractured and contorted limestone (with mica and marble) interbedded with slates and quartzite.

had no direct relation to the ore deposits, time was not given to a detailed study of those rocks.

The intrusive rocks later than the Cassia batholith are locally referred to two groups, those belonging to the lower or coarse grained porphyry, and those belonging to the upper or fine grained porphyry. Of these, the lower porphyry sill is the most extensive, and crops out in a wide belt almost completely encircling the district. The upper porphyry occurs mainly as small pipes or dikes cutting across the bedding planes of the Wardlaw shale and Vipont

limestone, though locally it assumes a sill-like form. Lithologically, the lower porphyry is a fine grained, even textured rock, containing phenocrysts of quartz and feldspars from 5 mm. to 15 mm. in diameter. It is usually light gray, but often possesses a distinct greenish hue. The upper porphyry is a light gray to grayish tan, fine grained rock, containing phenocrysts of quartz and feldspars from 2 mm. to 5 mm. in diameter. The phenocrysts of quartz are predominantly larger than those of the feldspars. Except for textural differences the two rocks are similar, the primary minerals of both including andesine, quartz, and sanidine, with minor amounts of magnetite and apatite. Secondary minerals are chlorite, calcite, white mica, and leucoxene. Quartz, sanidine, and andesine make up the phenocrysts in both rocks. The fine grained matrix is composed mainly of these same minerals in about equivalent proportions. These rocks are quartz-sanidine rhyolite porphyries. They represent different phases of the same intrusion, and though conveniently referred to two groups, are strictly speaking of one rock type, differing essentially only as to texture and mode of occurrence.

ORE DEPOSITS.

General. All the ore deposits thus far found in the district are replacements in limestone and all have an irregular, patchy distribution, whether oxides or sulphides. Deposits are similar in shape and form in each of the three limestone formations recognized in the district, but deposits in the Vipont limestone are much more abundant and widespread. The irregularity and bunched distribution of the ores has in part accounted for the delayed and sporadic development of the district. It has never been possible to block out ore with any success in any of the mines, nor to predict the character of ore or size of a single, small orebody.

The distribution of the mines and prospects within the district is clearly related to the distribution of the late intrusives (Fig. 1). Extensive prospecting has revealed that ore values are almost invariably associated with limestone in close proximity

to the porphyries and that the values in general diminish with distance from these rocks. Replacements have not been general, but in all cases have been localized by structural features within the limestones. Most notable of these features are the small crenulations in the limestone, along the bedding planes of which abundant secondary calcite has developed.

Accurate information as to the production of each of the mines in the district is not available; statistical reports give only the district production with no apportionment to the various mines. From available information, however, it is evident that the Vipont mine alone has yielded more than 95 per cent of the district's total production.

Production from 1873, when the first claim was staked, to 1899 aggregated approximately seven hundred tons with a value of twenty thousand dollars. Production from 1899 to 1917 has been summarized in the following table by Heikes:⁹

PRODUCTION FROM ASHBROOK DISTRICT 1899-1917.

Year.	Ore Mined.	Gold.		Silver.		Total Value.
	Short Tons.	Ounces.	Value.	Ounces.	Value.	
1899	225	37.17	\$ 768	18,245	\$10,947	\$11,715
1900	22	9.04	187	3,374	2,092	2,279
1901	200	3.30	68	1,639	983	1,051
1902	28	5.58	115	1,640	869	984
1903	91	7.75	160	3,189	1,722	1,882
1904	119	4.30	89	1,612	923	1,012
1917	27	3.74	77	1,400	1,153	1,330
	*712	70.88	\$1,464	31,099	\$18,869	\$20,153

* Also yielded 125 tons of concentrate.

During the period 1905 to 1917, work done in the district was principally for the purpose of holding claims, and the Midway tunnel and A-tunnel of the Vipont mine were completed. Active large scale development work in the district did not start until 1918, when the Vipont Silver Mining Company was formed by

⁹ Heikes, V. C.: Ore deposits of Utah. U. S. Geol. Surv. Prof. Pap. 111: 495, 1920.

a New York exploration company. From 1918 until 1923, when this company ceased exploration work, the district attained a high ranking position in the State's total production of silver. Production during these years is summarized below.

PRODUCTION FROM ASHBROOK DISTRICT 1918-1923.

Year.	Gold.		Silver.	
	Ounces.	Value.	Ounces.	Value.
1918	116.10	\$ 2,400	21,009	21,009
1919				
1920	1,024.27	21,188	525,853	573,180
1921	1,331.00	27,527	716,808	716,809
1922	2,976.03	61,520	1,043,671	1,043,761
1923	435.38		217,534	

The Vipont Silver Mining Company discontinued active operations on August 1, 1923, when buying under the Pittman Act ceased and the price of silver dropped from \$1.00 to \$0.64 an ounce. Production from this date until 1929, when the mining and milling machinery was sold and moved away from the mine, was small.

The mines of the district remained idle until 1934, when operations at the Vipont mine were renewed on a small scale. These operations have consisted mainly of mining small bodies of high grade ore and have proceeded sporadically to the present date. The total production from 1934 to the present has been about 300,000 ounces of silver and several hundred ounces of gold.

The Vipont Mine.

The orebodies of the Vipont mine occur in the Vipont limestone, between the overlying Wardlaw shale and underlying lower porphyry. They are not confined to a particular horizon within this formation, but are distributed from the porphyry footwall to the shale hanging wall, and usually conform to bedding planes (Fig. 2). Structural features within the limestone, though not clearly discernible in all cases, appear to have been the most im-

portant factors in localizing the ore deposits. The workings of the mine are along the northeastern flank of the synclinal fold forming the major structure of the district. Reflection of this fold is seen in the outline of the main levels of the mine; these main levels correspond in general to the contact between the Vi-



FIG. 2. Section A-A' through the Vipont mine showing general distribution of orebodies through the Vipont limestone.

pont limestone and the lower porphyry (Fig. 3). As shown above, this major fold is not simple in form. Superimposed upon it are numerous small crenulations, the largest of which have a roughly radial distribution with respect to the major fold. Close examination of the stope map of the mine reveals that the main stopes also have a roughly radial distribution with respect to the major fold. The main "stope runs" correspond to broad, complicated, anticlinal crenulations on the major fold. The intermediate areas between the main "stope runs" appear to represent the synclinal crenulations. Minor crenulations, together with small irregular slips, complicate these general structural features. Associated with the formation of these crenulations there has locally been development of much secondary calcite in stringers usually paralleling the bedding planes. Development of this calcite has been most extensive in the crests of the crenulations and ordinarily pinches toward the flanks. It should be under-

stood that these crenulations are not necessarily symmetrical, but show great variation in size, shape, and continuity.

In conjunction with these crenulations, the structure is further complicated by minor slips and localized zones of fracture.

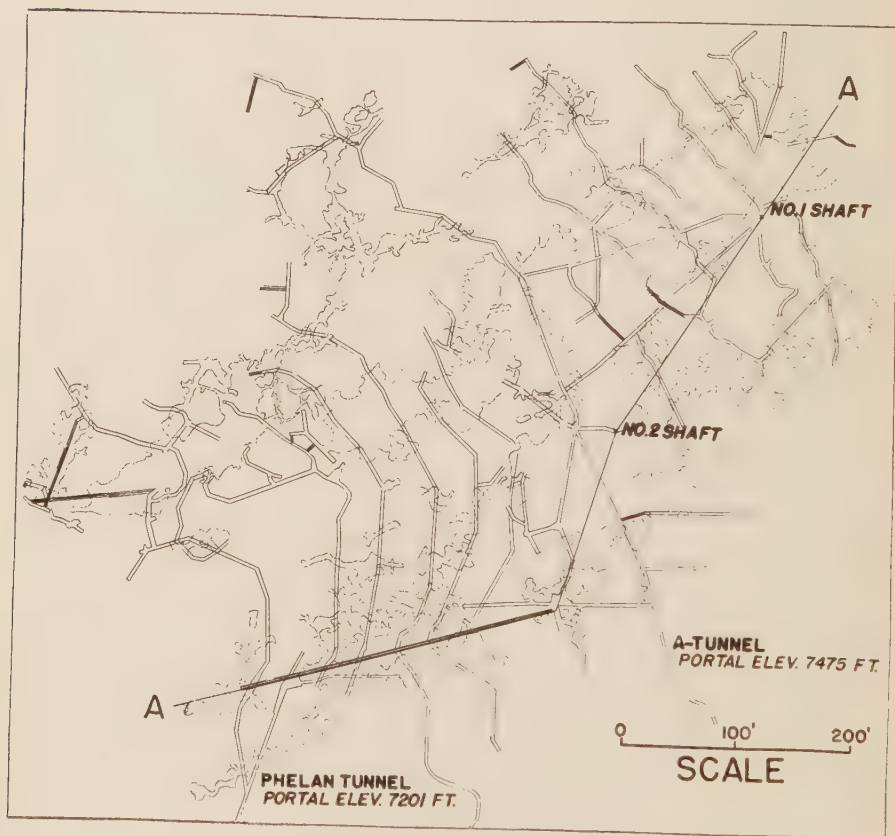


FIG. 3. Generalized stope map of Vipont mine.

These zones of fracture, like the apical portions of the crenulations, in which there has been extensive development of secondary calcite, have formed the most vulnerable areas of replacement by mineralizing solutions. Their intricate form and complex relation to each other account to a large extent for the great variations in the size and continuity of the orebodies.

However, replacement by ore-bearing solutions is not limited to these fractured areas. At present, it is not possible to predict the extension of particular fractured zones beyond known orebodies, or to determine in advance their relation to each other, though it seems possible that through detailed study this might be accomplished.

Size and Form of the Ore Deposits. The ore occurs generally in small patches and pockets of irregular form, connected by small stringers. Commonly they are elongated parallel to the bedding planes in the limestone, and have a roughly lenticular form across their shorter dimensions. The size of the orebodies



FIG. 4. Idealized sketch showing the relations which existed in two adjacent stopes in the "trespass" above A-level.

is extremely variable. An orebody several feet in diameter may in the course of a few feet connect with a scarcely visible stringer; this stringer may again expand into a sizable orebody. For the description of this relation of one orebody to another, the local expression "rolls" is used. These "rolls" correspond to minor crenulations in the limestone, and pinching of the ore is closely associated with the pinching of calcite stringers on the flanks of these crenulations. This relationship is clearly revealed by recent developments in the "trespass" above A-level (Fig. 4), where a small stringer of ore was followed down the flank of an elongate crenulation through almost barren rock into another orebody essentially paralleling the first.

The orebodies are most commonly parallel to the bedding planes of the limestone, but locally, as in Upper K-46 raise, the ore cuts across the bedding planes in a vertical pipe (Fig. 5). At the top of this pipe, the ore spreads out like an umbrella, the upper surface of which conforms to undulations in the limestone. In this case it appears that the pipe acted as a feeder to the upper

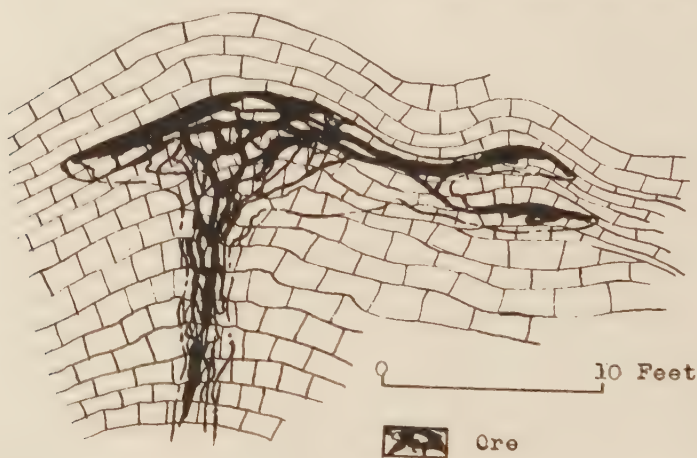


FIG. 5. Idealized sketch showing the relation of ore to the limestone in upper K-46 raise.

part of the orebody and that the resistant bed forming the hanging wall acted as a dam to the rising mineralizing solutions.

The above description has been primarily concerned with deposits of sulphide ore. Though the deposits of oxide ore are not as clearly defined, they appear to have corresponding relationships with the enclosing limestone.

Mineralogy of the Vipont Ores.

Hypogene Minerals. The minerals that are considered primary or hypogene in origin are those formed prior to or overlapping with the deposition of galena, which is apparently the latest of the primary minerals. The primary minerals include: rhodochrosite, sericite, quartz, pyrite, arsenopyrite, gold, spha-

lerite, chalcopyrite, argyrodite, tennantite, pearceite, pyrargyrite, an unidentified mineral, and galena.

Argentite was considered of primary origin in these ores by Vhay¹⁰ and by Foss,¹¹ who states: "Argentite is probably the essential primary silver mineral in these ores. Its most common occurrence is between quartz grains in the highly silicified limestone, but also filling minute fractures in the same grains." This association of argentite with quartz is not necessarily indicative of primary origin. The writer's observations have revealed no relations between argentite and known primary minerals which are certainly indicative of hypogene origin. Contrary to this, the preponderance of evidence is strongly in favor of a supergene origin for this mineral.

Rhodochrosite is a minor component of the Vipont ores, though locally, it is abundant. Specimens examined came from A-33 raise, where rhodochrosite comprised one of the principal introduced gangue minerals. It occurs in fractured limestone which is shot through by numerous stringers of calcite. Rhodochrosite has replaced both the massive limestone and the later calcite, but is much more extensively developed in the latter. In color it is usually the characteristic pink, though some specimens are markedly bleached. Much of the rhodochrosite is minutely vuggy, the vugs ordinarily being lined with well-formed, clear quartz crystals. In thin section or polished section, quartz is also seen to traverse the rhodochrosite in small irregular veinlets. It is notable that the quartz that forms the smallest veinlets is clear like that which lines the vugs, and that the quartz that constitutes the principal veins is dark in color. This color appears to be due to inclusion of a material resembling manganese dioxide. Here, as in most places, sulphides are more commonly associated with the dark quartz. The change in color from one quartz to the other is transitional and does not represent two separate

¹⁰ Vhay, J. S.: Unpublished professional report on the Vipont mine, March 23, 1937.

¹¹ Foss, A. L.: The geology of the Vipont mine. Unpublished undergraduate thesis, Univ. Minn., Dept. Geol., 1923, p. 18.

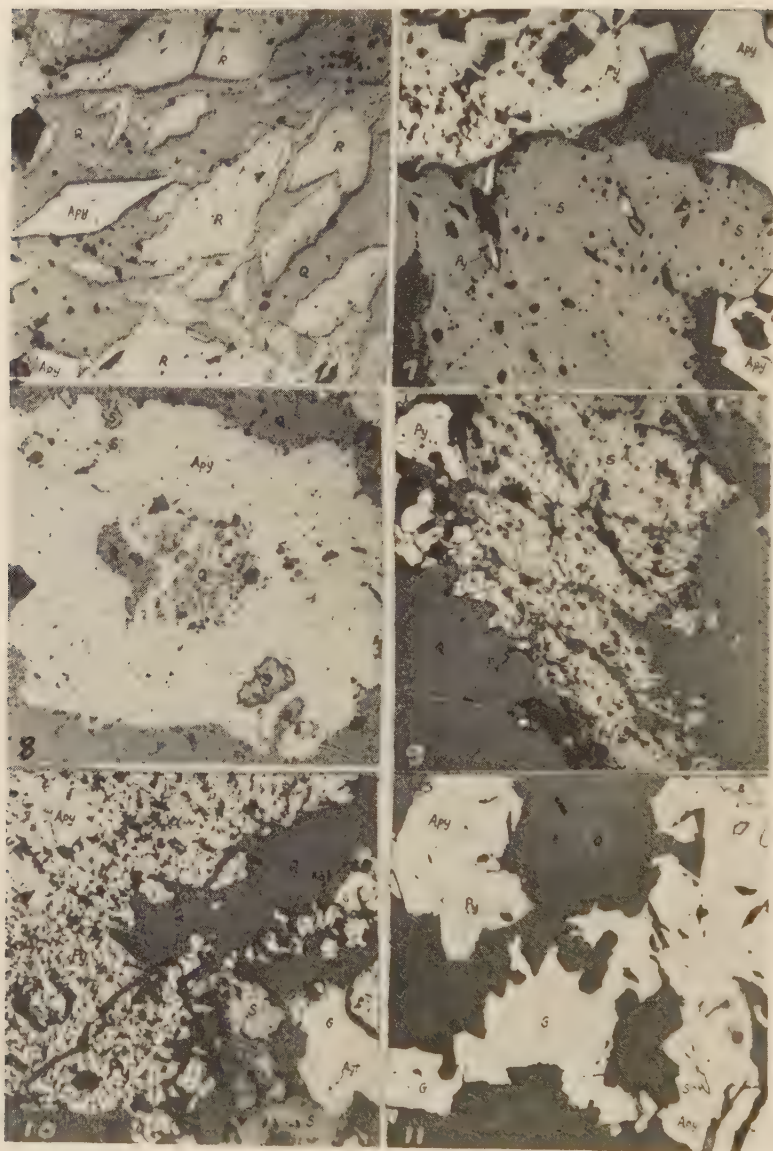


FIG. 6. Quartz (*Q*) filling fractures in rhodochrosite (*R*) and containing automorphic inclusions of arsenopyrite (*Apy*) and rhodochrosite. $\times 45$.

periods of deposition. Pyrite and arsenopyrite have not been observed in contact with rhodochrosite to the exclusion of quartz. These minerals are commonly found in the dark quartz occurring either at some distance from the main masses of rhodochrosite or occupying the darker central portions of quartz veins traversing the rhodochrosite. Pyrite and arsenopyrite are considered to be of a later phase in the sequence of mineralization than rhodochrosite and probably formed subsequent to the development of the first clear quartz.

The relationship between quartz and rhodochrosite is of special interest (Fig. 6). It is noted that quartz traverses the rhodochrosite in irregular veinlets, indicating that quartz is younger than the main masses of rhodochrosite. The edges of these veins show abundant automorphic outlines of rhodochrosite against quartz, and automorphic crystals of rhodochrosite are common inclusions within the quartz veinlets. Automorphic outlines of quartz crystals against rhodochrosite have not been observed. Larger masses of rhodochrosite characteristically show a marginal development of younger rhodochrosite in crystallographic continuity. Small veinlets of later rhodochrosite fill fractures, with slight replacement, in early rhodochrosite, but have never been observed to traverse quartz. From these relationships it is seen that in a strict sense, the quartz veinlets, though definitely later than the rhodochrosite, do not represent

FIG. 7. Pyrite (*Py*), arsenopyrite (*Apy*), and sphalerite (*S*) intergrown with quartz (*Q*). Note automorphic outline of quartz against pyrite and sphalerite at (*X*). $\times 45$.

FIG. 8. Inclusions of quartz (*Q*) and sphalerite (*S*) in arsenopyrite (*Apy*). $\times 80$.

FIG. 9. Quartz (*Q*) filling fractures in sphalerite (*S*). $\times 90$.

FIG. 10. Quartz veinlet (*Q*) traversing pyrite (*Py*) which is intergrown with arsenopyrite (*Apy*). Galena (*G*) interstitial in quartz and sphalerite (*S*) being replaced by argentite (*Agt*). $\times 80$.

FIG. 11. Galena (*G*) interstitial in quartz (*Q*) which conforms to the automorphic outlines of pyrite (*Py*) and arsenopyrite (*Apy*). Arsenopyrite containing inclusions of pyrite and with fractures filled by quartz and sphalerite (*S*). $\times 80$.

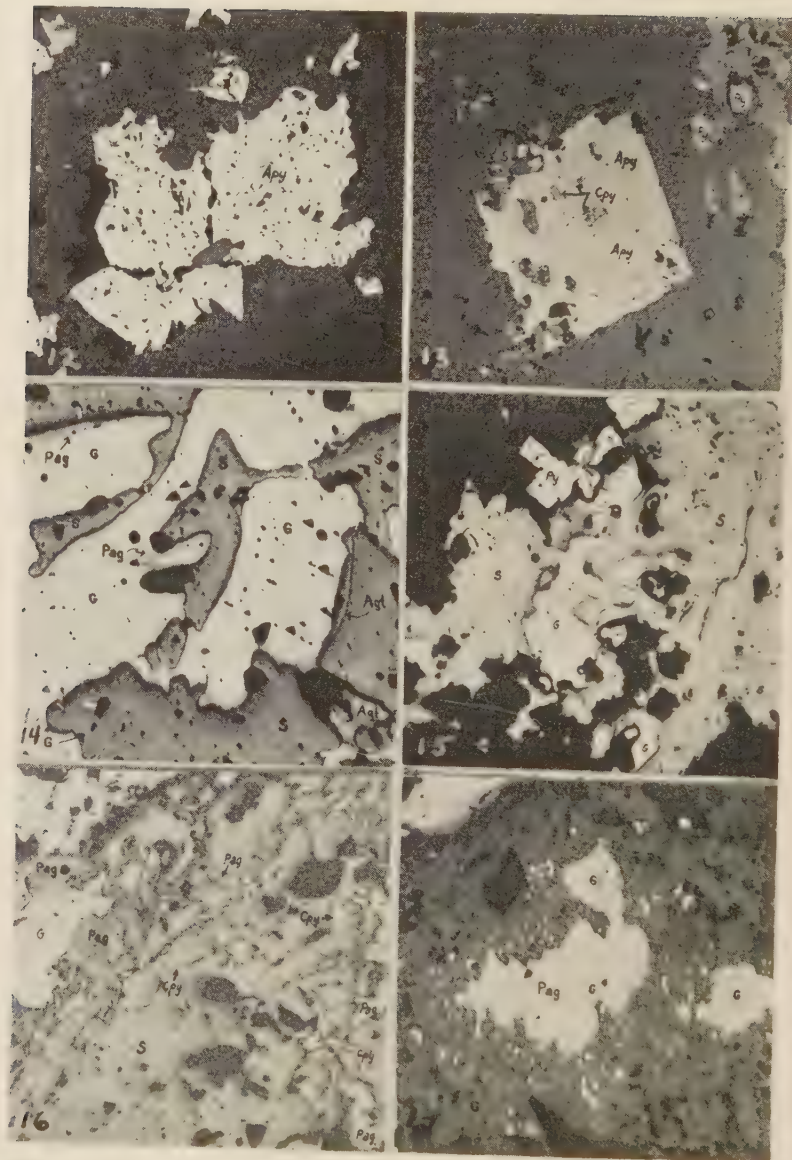


FIG. 12. Arsenopyrite (*Apy*) intergrown with quartz (*Q*). $\times 90$.

FIG. 13. Automorphic crystal of arsenopyrite (*Apy*) containing inclusions of sphalerite (*S*) and chalcopyrite (*Cpy*). Arsenopyrite enclosed in quartz (*Q*). $\times 90$.

simple filling of fractures in this mineral. The interpretation is that the rhodochrosite, while still in the process of crystallization, was fractured; that these fractures were filled by solutions carrying rhodochrosite, quartz and minor amounts of sulphides; that the crystallization of the rhodochrosite continued with the development of additions to old crystals and the formation of free automorphic crystals; that the crystallization of the rhodochrosite proceeded essentially to completion before quartz crystals commenced forming; and that quartz carrying inclusions of sulphides and rhodochrosite formed interstitially within these fractures, assuming in all cases the automorphic outlines of rhodochrosite. Forces which caused the fracturing may have arisen from several sources, but the close association with mineralization processes suggests that the principal forces involved were those incident to the penetration of the ore-bearing solutions.

Sericite in finely divided flakes is associated in small amounts with the earlier, clear quartz. In the later, usually darker colored quartz, this mineral is not ordinarily present. Its abundance with respect to the early formed quartz and marked decrease with the appearance of the early sulphides, suggests that it belongs to the early stage of quartz crystallization. Sericite probably formed contemporaneously with the first quartz and slightly overlaps the earliest sulphides.

Quartz is the most important introduced gangue mineral in the Vipont ores, formed by replacement, chiefly of calcite stringers within the fractured limestone. As a rule, the last formed quartz in the central regions of the orebodies is finer grained than the earlier quartz and contains dark inclusions resembling

FIG. 14. Galena (*G*) interstitial in sphalerite (*S*) and intergrown with pyrrargyrite (*Pag*). Note inclusions of galena in sphalerite. $\times 80$.

FIG. 15. Galena (*G*) intergrown with pyrrargyrite (*Pag*) and interstitial in sphalerite (*S*). Quartz (*Q*). Pyrite (*Py*). $\times 75$.

FIG. 16. Galena (*G*), chalcopyrite (*Cpy*), and pyrrargyrite (*Pag*) filling fractures in sphalerite (*S*). Pyrrargyrite intergrown with galena and chalcopyrite. $\times 250$.

FIG. 17. Pyrrargyrite (*Pag*) intergrown with galena (*G*) which has replaced calcite (*C*). $\times 90$.

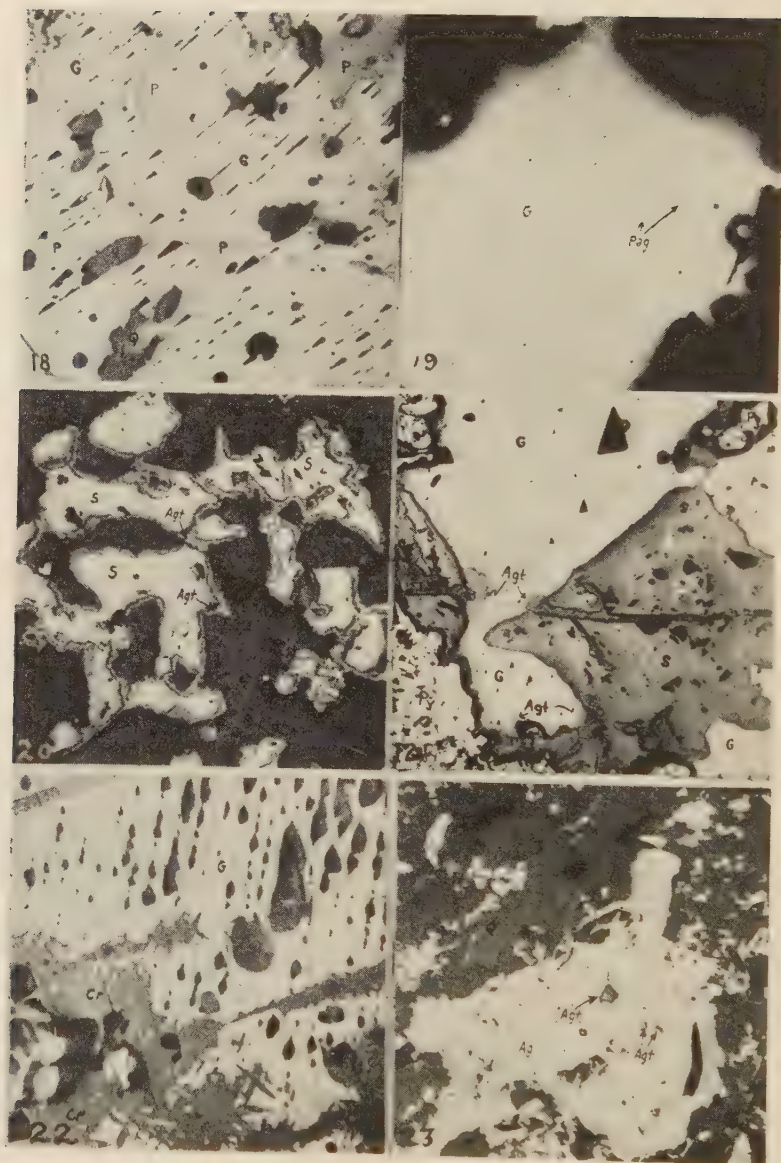


FIG. 18. Inclusions of pearceite (*P*) in galena (*G*). Dark gray mineral is quartz (*Q*). $\times 90$.

FIG. 19. Inclusions of pyrargyrite (*Pag*) in galena (*G*). $\times 250$.

manganese dioxide. It is possible, as has been suggested by Vhay,¹² that this dark material is inherited from the replacement of surrounding limestone which contains similar material. However, this is not in harmony with the fact that the earlier quartz, usually directly associated with the limestone, is clear. As pointed out above, the two quartz types appear to represent phases of the same period of continuous crystallization, since the variation in color and amount of inclusionary material between the two is gradational.

Quartz displays mutual crystalline boundaries with pyrite, arsenopyrite, and sphalerite (Fig. 7), though it ordinarily conforms to the automorphic outlines of these minerals. It has been observed associated with sphalerite as inclusions in crystals of arsenopyrite (Fig. 8), and filling fractures in pyrite, arsenopyrite, and sphalerite (Figs. 9 and 10). Late sulphides usually have an interstitial relationship to the quartz.

Pyrite, constituting the most abundant and prominent sulphide of the ores is almost invariably associated with quartz, arsenopyrite, and sphalerite. Both massive and crystalline forms are known. Large bodies of massive pyrite were reported in the early workings of the mine, where, together with arsenopyrite, it comprised the principal part of the large replacement sulphide bodies just below the Wardlaw shale. Most commonly it occurs in the form of cubes and retains its automorphic outline against arsenopyrite (Fig. 11), though some mutual crystalline bounda-

¹² Vhay, *op. cit.*

FIG. 20. Sphalerite (*S*) replaced peripherally by argentite (*Agt*). $\times 90$.

FIG. 21. Galena (*G*) interstitial in sphalerite (*S*). Argentite (*Agt*) replacing sphalerite along fracture. Note that fracture does not extend across galena. Chalcopyrite inclusions in sphalerite at (*X*). Axial mineral in argentite veinlet unidentified. $\times 90$.

FIG. 22. Cerussite (*Cr*) replacing galena (*G*) along cleavage directions. $\times 90$.

FIG. 23. Native silver (*Ag*) containing remnants of argentite (*Agt*). Dark gray mineral quartz (*Q*). $\times 80$.

ries occur between these two minerals. This relationship indicates that, in general, pyrite is older than arsenopyrite, but that there has been some overlap in their crystallization.

Sphalerite commonly conforms to the automorphic outlines of pyrite crystals. Inclusions of pyrite in sphalerite are rather common and show an inclination toward rounding; inclusions of sphalerite are also found in pyrite, but not as often. Deposition of sphalerite was evidently later than pyrite, though a slight overlap is apparent between the two minerals.

Against galena and all the sulpho-salts of silver, pyrite usually retains its automorphic form. These minerals transect pyrite in small veinlets filling fractures and also have an interstitial relationship to quartz that cuts the pyrite in veinlets (Fig. 11). Pyrite, therefore, is considered to have preceded the deposition of galena and all the sulpho-salts of silver.

Arsenopyrite, next to pyrite, is the most conspicuous and abundant of the sulphides comprising the Vipont ores. It has been less susceptible to oxidization than pyrite, resulting in more general distribution throughout the mine, and samples of unaltered arsenopyrite are obtainable from the highest workings. Like pyrite, it occurs in both massive and disseminated crystalline form, the latter predominating. Well formed crystals of arsenopyrite are commonly observed in hand specimens.

In the polished specimen, arsenopyrite appears as a pale yellow mineral, somewhat lighter in color than pyrite. It is nearly always associated with quartz, pyrite, and sphalerite. Mutual crystalline boundaries with quartz are common (Figs. 12 and 13), though automorphic outlines of arsenopyrite against quartz are more prevalent. Late quartz fills fractures in arsenopyrite. Inclusions of chalcopyrite, quartz, and sphalerite in arsenopyrite have been noted frequently (Figs. 8 and 13). Sphalerite commonly conforms to the automorphic outline of arsenopyrite, though mutual inclusions and mutual boundaries are not uncommon. Arsenopyrite is considered to be somewhat older than sphalerite, but overlapping the period of crystallization of that mineral. Galena and the late silver salts retain the same relation-

ships toward arsenopyrite as toward pyrite; they are definitely later.

Gold in the Vipont ores is known only from assays with widely divergent values of this metal. Gold has never been recognized in the hand specimen of these ores, and it is only doubtfully recognized in polished sections. A mineral resembling gold occurs as inclusions, associated with inclusions of chalcopyrite, in arsenopyrite. It is lighter in color than the chalcopyrite and etches black with potassium cyanide. The inclusions are roughly equidimensional, and occasionally exhibit straight contacts with arsenopyrite. The exact age relationship of these inclusions to arsenopyrite is not known, but they appear to be roughly contemporaneous with it and correspond to the same period of crystallization as that to which the chalcopyrite inclusions belong. The samples in which these inclusions were recognized came from lower A-73 raise. The gold-bearing arsenopyrite displays relations with other minerals and other arsenopyrite which suggest that it was among the earliest of the arsenopyrite to form.

Sphalerite is found in unoxidized or only partially altered ore. It is not a conspicuous mineral in the hand-specimen, occurring in smaller amounts than either pyrite or arsenopyrite. It is, however, a rather conspicuous mineral in polished sections, where its recognition is made easy by the fact that it invariably contains abundant inclusions of chalcopyrite. Its color is a pinkish-gray by reflected light. As shown above, sphalerite, though overlapping both arsenopyrite and pyrite, is largely later than both. Automorphic boundaries with quartz are common, but the reverse relation also occurs. Later quartz, however, fills fractures in sphalerite. No sphalerite formed subsequent to this period of fracturing. Galena conforms to the automorphic outlines of sphalerite and is usually interstitial within it (Figs. 14 and 15).

Chalcopyrite is a relatively minor component of these ores and is rarely observed in the hand specimen. As in P-41 raise, however, it has been prominent in some stopes. Ordinarily, it is closely associated with ores carrying abundant sphalerite, pyrite, and arsenopyrite.

Two forms have been observed in polished section: inclusions in sphalerite and arsenopyrite (Figs. 13 and 15), and small veinlets and interstitial bodies in the earlier sulphides (Fig. 16). Inclusions in arsenopyrite are larger, but less abundant than in sphalerite, averaging about 0.03 mm. in the arsenopyrite as compared with 0.004 mm. for the sphalerite. Though rounded contacts with the arsenopyrite are most prevalent, straight contacts, which may represent crystal faces are not uncommon. Inclusions within automorphic crystals of arsenopyrite suggest that these straight contacts are not related to crystallographic directions within the arsenopyrite, but that they probably represent crystal faces of the chalcopyrite.

Inclusions of chalcopyrite in sphalerite are of especial interest. Their invariable presence in the sphalerite of these ores, serves as a criterion in identifying this mineral. In form, the inclusions are distinctly irregular, no one shape predominating. There is, however, some tendency toward elongate grains, the long dimensions of which are parallel to crystallographic directions within the sphalerite. Extension of elongate blebs to the point of coalescence with other blebs in line, has produced vein-like forms within the sphalerite. Rarely these vein-like forms have been observed to intersect, and no apparent thickening occurs at their junction. In most sphalerite grains the inclusions have a bunched distribution, large areas within the grains being apparently devoid of inclusions, while adjacent areas are densely populated. There is a marked tendency for thickly populated areas to occur near but not at the edges of the sphalerite grains. With contiguous grains, such a condition results in the formation of "runs," in which there are no inclusions of chalcopyrite. It is not uncommon for chalcopyrite and galena to be found as elongate inclusions occupying the axial positions of these "runs."

In the polished sections of ores taken from lower A-73 raise, chalcopyrite fills fractures in sphalerite (Fig. 16). It has also been observed as irregular masses intergrown with galena interstitial in quartz and sphalerite. It is noteworthy that wherever chalcopyrite in veinlets or irregular masses comes in contact with

sphalerite, there is a marked increase in the abundance of chalcopyrite inclusions in the sphalerite. A similar relationship has been described by Buerger¹³ for the unmixing of chalcopyrite from sphalerite from the ores of Bingham Canyon, Utah. Here it was observed that when sphalerite was heated in contact with chalcopyrite to temperatures of 350 to 400° C. numerous small blebs of chalcopyrite developed within the sphalerite near the contact with the chalcopyrite. Buerger says:

This development of minute chalcopyrite blebs in the sphalerite adjacent to large masses of chalcopyrite can only be accounted for by a mixing and unmixing process having taken place. The chalcopyrite dissolved in the adjoining sphalerite to form a solid solution of the two minerals. . . . Since the chalcopyrite in solution was more concentrated near the large mass of that mineral, more blebs have been segregated close to the mass, diminishing in number and finally disappearing farther out in the sphalerite.

This may account for the extra density of chalcopyrite inclusions in sphalerite next to chalcopyrite in the Vipont ores. Though it is clear that the larger masses of chalcopyrite are later than the sphalerite, sufficient heat in the mineralizing solutions may have been present subsequent to the crystallization of the chalcopyrite to cause a diffusion of chalcopyrite into solid solution with sphalerite. Later unmixing would thus reveal a concentration of chalcopyrite in sphalerite adjacent to larger chalcopyrite areas. As will be seen, chalcopyrite crystallization was essentially complete before the precipitation of galena and the sulpho-salts of silver.

Galena is a minor constituent of the Vipont ores. It is not commonly recognized in the hand specimen and where observed is usually in small grains. The largest specimens observed came from lower P-2 raise. In nearly all cases galena is found associated with enriched or partially oxidized ore and is usually partially altered to secondary minerals.

In the polished section galena appears as a white mineral usually intergrown with the sulpho-salts of silver interstitially in the

¹³ Buerger, N. W.: The unmixing of chalcopyrite from sphalerite: *Am. Min.*, XIX: 528, 529, 1934.

earlier sulphides (Fig. 15). It conforms to the automorphic outlines of quartz, pyrite, arsenopyrite and sphalerite (Fig. 20) and fills fractures in the last three of these minerals. Inclusions of galena in sphalerite are common, though not nearly as abundant as chalcopyrite. These ordinarily have rounded outlines but galena inclusions conforming to the crystal outlines of sphalerite have been repeatedly observed. It is not uncommon for the galena inclusions to occupy "runs" parallel to crystallographic directions within the sphalerite, in which case, the inclusions are linearly arranged elongate, rounded masses, similar in shape, though generally larger, than chalcopyrite inclusions occurring under similar conditions. Galena is considered to be definitely later than sphalerite and to occupy spaces between sphalerite crystals. Small masses of chalcopyrite are intergrown with galena within sphalerite. Galena is also definitely later than pyrite and arsenopyrite and formed after a period of local fracturing and concomitant quartz-deposition.

Galena is commonly associated with highly silicious ores, but in some samples taken from N-43 raise, galena and pyrargyrite directly replace calcite in the wall-rock (Fig. 17). In these same sections, galena, where associated with quartz, always assumes an interstitial relationship with that mineral. Automorphic inclusions of quartz in galena are common, but inclusions of galena in quartz are rare, if not wholly lacking. These relationships indicate that the precipitation of galena and the sulphosalts of silver persisted longer than the deposition of late quartz; locally they replaced the calcite of the wall-rock directly.

In polished sections of ore coming from X-9 stope a mineral has been recognized which, in repeated tests, gave reactions corresponding to those noted by Short¹⁴ for argyrodite, although the presence of germanium has not been verified. It is light gray and possesses slight anisotropism. The mineral occurs intergrown with chalcopyrite interstitially in contact with quartz and

¹⁴ Short, M. N.: Microscopic determination of the ore minerals. U. S. Geol. Surv. Bull. 825: 85, 1931.

pyrite and is considered to be about the same age as the chalcoppyrite.

The ruby silver pyargyrite is quite often observed in the ores of the Vipont mine, but is ordinarily too finely disseminated to be definitely identified in the hand specimen. It is almost always associated with galena-rich ore and is usually interspersed in that mineral.

In polished section, this pyargyrite is light blue and shows a deep red internal reflection. Identification by etch tests was supplemented by microchemical tests proving the antimony content of the mineral, thus distinguishing it from proustite, the arsenical ruby silver. Commonly, pyargyrite occurs as automorphic inclusions in galena (Fig. 19), though it also occurs intergrown with this mineral. Specimens taken from X-9 stope show a particularly good development of these inclusions. They are irregular, though there is a definite tendency toward elongate-rectangular and diamond-shaped outlines. The average maximum diameter for samples from X-9 stope is about 0.025 mm. The width of longer rectangular forms is usually about one fifth of the maximum diameter. Boundaries are straight and are definitely crystal faces. The orientation and distribution of the inclusions with respect to each other and with respect to crystallographic directions within the galena indicate that no influence was exercised by the galena in their distribution.

Of the primary silver minerals found in the Vipont ores, pyargyrite is by far the most abundant and is responsible for most of their silver content.

Pearceite, recognizable only in polished section, is almost invariably associated with pyargyrite. It is slightly more gray than galena, shows slight anisotropism, and has a dark red internal reflection. Its identification is based both on etch and microchemical tests. Wherever it has been observed in contact with the earlier sulphides, the automorphic outlines of these minerals persist. Like pyargyrite, it is found as inclusions in and intergrown with galena (Fig. 18). Together with pyargyrite,

it fills fractures in the earlier sulphides. It is considered to be essentially the same age as pyrargyrite and galena.

Tennantite was identified in polished sections of specimens from A-103 raise. It is light gray, about the same color as pearceite, but with slightly higher relief. It occurs intergrown with pyrargyrite and galena and is interstitial to quartz and the early sulphides. It is believed to be essentially contemporaneous with pyrargyrite.

In polished section, a pink mineral in grains too small to be identified is associated with pearceite and tennantite. It appears to be about the same age as the pearceite.

Supergene Minerals. The hypogene ores of the Vipont mine have been extensively modified by supergene processes. The extent to which alteration in the primary ores has proceeded has been dependent on the ease and readiness of access to the ores by the modifying agents. Thus, it is clearly evident that secondary alterations are intimately related to structural features within the orebodies and wallrock. It is not possible to divide the Vipont mine into zones in which either primary, enriched, or oxidized ores predominate. Oxidized and enriched ores are not uncommon in the lowest workings of the mine, and essentially primary ores are not unknown in the highest levels of the mine. It is true, however, that oxidized ores are more abundant in the upper levels, and that supergene enrichment has been greater in the intermediate levels. Single orebodies are usually modified by both enrichment and oxidation. Active groundwater circulation is usually confined to local zones of fracturing and the modification of an orebody depends on its proximity to one of these zones. If a general groundwater table exists in this mine similar to that ordinarily assumed to conform with superficial topographic features, it has not played a part in the division of the ores into zones.

The following minerals have been noted as alteration products of the primary ores resulting from processes of downward enrichment: undetermined lead silver salt, intermediate between galena and argentite; argentite, covellite, chalcocite, cerussite, and possibly native silver. Predecessors of these minerals are mainly

sphalerite, galena, and the sulpho-salts of silver. Arsenopyrite has locally been replaced by argentite.

Occurring between galena and argentite in the enriched ores is a narrow band of a mineral whose formation invariably precedes the replacement of galena by argentite and appears to represent a transition from one mineral to the other. In color and hardness it is like galena and reacts similarly to tests for that mineral.¹⁵ In fresh untreated sections it is indistinguishable from galena, but is brought out in striking contrast by staining the galena with hydrogen peroxide. This relationship is particularly well shown in samples from A-10 raise and lower A-73. Galena has been slightly replaced by covellite, cerussite, and chalcocite; argentite extensively replaces sphalerite; but this intermediate mineral occurs only between argentite and galena. Similar relationships between galena and argentite have been noted by Bastin¹⁶ in the ores of Tonopah, Nevada, and he interprets the transitional mineral as a double sulphide of lead and silver.

Argentite is by far the most abundant silver mineral of the enriched ores and is economically the most important. Ordinarily it is not recognized in hand specimen, though locally it has been found in fairly large masses, intimately associated with wire silver. Argentite is found in nearly all polished sections of the sulphide ore, regardless of the part of the mine from which the specimens come. It is moderately light gray with a marked green tinge. It replaces galena and sphalerite (Figs. 20 and 21) and, locally, arsenopyrite. Alteration of the ruby silvers has mainly been to argentite. Sphalerite displays striking peripheral replacement by argentite, though in places its crystallographic directions clearly control the replacement. Laths of covellite, intimately intergrown with the argentite, are common in the replacement of both sphalerite and galena, and a small amount of chalcocite is often associated with the covellite. Small veinlets of argentite in sphalerite sometimes have a central parting of an

¹⁵ Short: *ibid.*, p. 73.

¹⁶ Bastin, E. S.: The genesis of the ores at Tonopah, Nevada. U. S. Geol. Surv. Prof. Pap. 104: 21-23, 1918.

apparently earlier mineral which may be cerussite or, quite possibly, a silver haloid. This mineral has not been observed to replace sphalerite directly, but is always separated from it by argentite. It may represent a replacement of elongate galena inclusions which formerly occupied the spaces between intergrown sphalerite crystals, since galena with such relationship to sphalerite is quite common in the primary ores. Replacement of galena by argentite has not been as extensive as the replacement of sphalerite.

Corresponding to the observations of Foss,¹⁷ the present writer has observed argentite "between quartz grains . . . and filling minute fractures in these same grains." However, in such cases, the argentite is almost invariably intergrown with small amounts of covellite or is connected with argentite which, due to its relations and associations with other minerals, can definitely be considered to be of secondary origin. Evidence which would conclusively indicate a primary origin for argentite in these ores has not been observed.

Covellite and chalcocite, rarely recognized in hand specimens, occur only in small amounts as replacements of chalcopyrite, sphalerite, and galena. Both minerals commonly occur intergrown with argentite in the replacement of galena and sphalerite. As seen in samples from A-73 raise, covellite, intimately intergrown with cerussite, is found replacing galena.

Cerussite often replaces galena (Fig. 22), and is occasionally seen as a coating on ores rich in galena.

A mineral which resembles native silver in etch tests and color is often found intergrown with argentite in enriched ores. Inclusions of this mineral in argentite are too small to make determinative tests.

Oxidized Minerals. A large number of minerals have been recognized in the oxidized ores, but it was generally impossible to discover any consistent relationships between them. They are native silver, malachite, azurite, cuprite, native copper, orpiment, realgar, cerargyrite, limonite, hematite, anglesite, and calcite.

¹⁷ Foss: *op. cit.*, p. 18.

Many of these minerals occur in very small quantities and not always in association with other minerals of the group. It is therefore impractical to attempt to relate them to any particular phase of the oxidization processes.

Next to argentite, native silver is probably the most important mineral, occurring abundantly in locally oxidized and enriched ores throughout the mine, but with the largest amounts in the intermediate levels.

Native silver occurs in the ores most commonly as wire, in thin flakes, and in well-formed, tiny crystals. Druses in the richer ores are often partially filled with curling wires of native silver, generally associated with minor amounts of argentite from which the silver probably emanated. Wire silver has been observed up to one eighth of an inch in diameter, but ordinarily it is smaller. On larger wires of silver, there are developed nicely formed tiny cubic crystals of silver which give the wire a punctate appearance. Tiny flakes of silver have been observed clinging to the limestone hanging wall of the orebodies, or plastered on masses of sulphide. Native silver frequently replaces argentite (Fig. 23).

Malachite and azurite are locally present as stains and as fracture-fillings throughout the oxidized ores.

Cuprite was recognized in association with a small amount of native copper in a specimen of partially oxidized ore from K-level. Small amounts of pyrite and arsenopyrite still remained in the specimen, but none of the earlier copper minerals could be recognized.

Orpiment and realgar occur in small amounts as thin, dust-like coatings on arsenopyrite in partially oxidized ores.

Cerargyrite may occur in the ores. A small amount of material taken from oxidized ores on K-level has the general appearance of cerargyrite and reacted positively to a microchemical test for silver. That the mineral is probably present in the ores is suggested by the presence of silver in a solution derived from treating the oxidized ore with concentrated ammonium hydroxide.

Limonite and hematite occur in all the oxidized ore and are

locally prominent throughout the mine. Hematite imparts a much deeper color to the ores than limonite.

Secondary calcite is prevalent, and locally, cavities are lined with large well formed crystals.

Anglesite is found associated with cerussite locally in oxidized zones, but never occurs in large quantities.

Though sphalerite is an important component of the primary ores, no secondary zinc minerals were found. That they are present, however, is suggested by small quantities of zinc in assays of the oxide ores. It is likely, considering the country rock and the usual presence of considerable calcite in the oxidized ores, that smithsonite is the form in which the secondary zinc exists.

Paragenesis. Due to two episodes of fracturing, the deposition of the hypogene minerals can be divided into three periods. The deposition of rhodochrosite is separated from the deposition of the later minerals by a period of fracturing, the fractures being filled with quartz and minor amounts of sulphides. Galena and the sulpho-salts of silver are interstitial in quartz that fills fractures in pyrite, arsenopyrite, and sphalerite. The three phases of the mineralization thus indicated are (1) a period in which rhodochrosite was formed to the exclusion of other minerals, (2) a period in which the dominant minerals formed included quartz, pyrite, arsenopyrite, sphalerite, and minor amounts of chalcopyrite, and (3) a period in which galena and the sulpho-salts of silver predominated over all other minerals. Economically, the last of these periods has been by far the most important, though the second phase appears to have produced the gold values of the ore.

The paragenetic sequence of the ore minerals is shown graphically in Table 2.

Tenor of the Ores. In discussing the tenor of the ores it is necessary to distinguish between the kinds of mining methods used in recovering the ore. It is evident from the patchy distribution of the ore, and the variation in size and form of the ore-bodies, that the average value of recovered ore depends directly on the method of recovery. Operations in quest of ore suitable

TABLE 2.

PARAGENETIC SEQUENCE OF THE MINERALS IN THE VIPONT ORES.

Minerals.	Hypogene Minerals.	Products of Supergene Enrichment.	Products of Oxidation.
Rhodochrosite <i>fracturing</i>	—		
Sericite	—		
Quartz	—		
Pyrite	—		
Arsenopyrite	—		
Gold	—		
Sphalerite	—		
Chalcopyrite <i>fracturing</i>	—		
Galena	—		
Argyrodite	—		
Pyrargyrite	—		
Pearceite	—		
Tennantite	—		
Unidentified*	—		
Unidentified†		—	
Argentite		—	
Covellite		—	
Chalcocite		—	
Cerussite		—	X.....
Native silver		—	X.....
Malachite			X.....
Azurite			X.....
Cuprite			X.....
Native copper			X.....
Orpiment			X.....
Realgar			X.....
Limonite			X.....
Hematite			X.....
Calcite			X.....

* Unidentified mineral associated with sulpho-salts of silver in primary ores.

† Unidentified mineral intermediate between galena and argentite in the enriched ores.

for milling, and operations in quest of high grade ore suitable for direct shipment have both been carried on. Nearly all the high grade smelting ore recovered is screened, much of it underground. The values are principally found in the minus $\frac{1}{2}$ inch fines.

Two hundred composite analyses, each composed of ten grab-samples from freshly blasted high grade ore at different localities throughout the mine, show an average silver content of 27.06 fine ounces, and an average gold content of 0.078 ounce per ton. Individual orebodies have been known to carry as much as 10,-

000 ounces of silver and 4 to 5 ounces of gold per ton. The ratio of gold to silver is highly variable and there seems to be no consistent relationship of tenor to locality. Out of 63,710 tons of ore mined during 1922, the average recovery per ton was 0.046 ounce of gold and 16.3 ounces of silver.

Temperature of Formation of Primary Ores. Deposition of the minerals of the primary sequence is divisible into three general phases. All of the minerals of the first two phases are found under a wide range of temperature conditions and are thus not useful in the determination of the temperature at which the ores were formed. The sulpho-salts of silver in the later phase, on the other hand, are characteristically developed under low temperature conditions. Since chalcopyrite overlaps the deposition of these minerals and the earlier sulphides, it appears that deposition was from cooling solutions which even in their first stages had temperatures not much above those at which the sulpho-salts of silver were formed. The fine-grained texture of the ores corroborates the conclusion that the ores were formed under low temperature or epithermal conditions.

Character of Hypogene Solutions. As carbonates are in general deposited only from neutral or basic solutions, the appearance of rhodochrosite as the initial mineral of the primary sequence would seem to indicate that the early mineralizing solutions were of this character. The appearance of silica has no particular significance in the interpretation of the character of the solutions; this applies also to the presence of arsenopyrite, chalcopyrite, galena, and the sulpho-salts of silver. The presence of sphalerite suggests neutral or basic solutions, though this mineral may be precipitated from either acid or basic solutions. Wurtzite, which would indicate acidity, has not been recognized in these ores.

The presence of pyrite rather than marcasite also suggests basic or neutral solutions. Dana¹⁸ states that when pyrite is deposited from rising solutions, these solutions are usually basic.

A final bit of evidence as to the composition of the solutions

¹⁸ Dana, E. S.: A Textbook of Mineralogy, 4th edit. rev. John Wiley & Sons, Inc., New York, 1932, p. 434.

lies in the type of wall-rock in which the mineral deposits were formed, that is, it is unlikely that acid solutions could exist long in contact with the carbonates of the wall-rock.

It is concluded that at least during the main period of the mineralization the ore-forming solutions were either neutral or slightly alkaline, more likely the latter.

Other Mines and Prospects.

Skoro Mine. This mine is situated approximately a thousand feet southeast of the Vipont camp and has about the same elevation as A-portal of the Vipont mine. It was originally located in 1922 by a Mr. Skoro, then employed by the Vipont Silver Mining Company, and is opened by a 763 foot tunnel through the lower porphyry into the underlying Sentinell limestone, from which drifts have been driven in three directions. In all, approximately 1,300 feet of development work have been completed.

No important shipments of ore have been made from this mine. The tenor of the ore has been very erratic and, except for small pockets, has been generally low. The ore shipped has all been carefully selected screenings of the mined ore. Like the Vipont mine, the values are principally found in the fines. During the process of development work in the fall of 1936 the following assays were run.

SOME ASSAYS OF THE ORES FROM THE SKORO MINE.

Assay.	Gold.	Silver.	Location.
	Ounces per Ton.	Ounces per Ton.	
1	0.00	1.68	Unknown
2	0.34	152.12	"
3	0.06	14.04	East drift
4	0.005	2.80	North drift
5	tr.	2.00	" "
6	tr.	1.68	" "
7	0.02	10.70	" "
8	0.015	5.50	" "
9	0.02	19.37	" "

The occurrence is similar in many respects to that of the Vipont mine, though all the ore thus far found is confined to the

Sentinell limestone. The ore occurs as thin, scattered stringers intimately associated with stringers of secondary calcite along the bedding planes of the limestone. Rhodochrosite is locally abundant and, as in the Vipont mine, extensively replaces the secondary calcite stringers. Silicification of the wall-rock has not been as extensive as in the Vipont mine. The sulphide ores are usually soft and are not readily adaptable to study in polished section. A close examination of hand specimens, however, revealed essentially the same group of primary minerals present in the Vipont ores, though these ores are not nearly as extensively altered by processes of oxidation and enrichment.

Sentinell Group. The Sentinell workings are a group of shallow workings in the Sentinell limestone, situated about 1,500 feet northeast of A-portal of the Vipont mine (Fig. 1). They are very irregular, and the ore seems to have been found in patches and pockets along small slips and crenulations in the limestone. Except for some prospecting, active work has not been done in this group of workings since about 1922, when a small shipment of high grade ore was made from the lower workings. It is noteworthy that, compared with the Vipont ores, these ores have higher gold values. The ore is highly oxidized, though small pieces of essentially unaltered sulphides have been found.

Francis-X Mine. This mine was caved at the time of the writer's visits to the district and the workings were not accessible. The mine consists of a tunnel at equal elevation with the A-portal of the Vipont mine driven S. 75° E. through the basal part of the Phelan limestone into the Wardlaw shale. So far as known, the base of the shale has never been reached and no ore has been removed from the mine.

Midway Tunnel. Accurate information about this tunnel was not available. The tunnel is approximately 1,550 feet long and is driven through the Wardlaw shale into the Vipont limestone. The elevation of the portal, equal to that of the Phelan tunnel, is 7,201 feet above sea level. When active exploratory work by the Vipont Silver Mining Company ceased in 1923, A-level of the Vipont mine was being driven westward to connect with a raise

to be driven from the Midway tunnel. Accurate information as to the occurrence of ore in the Midway tunnel was not available to the writer, though Mr. H. K. Lake states that some was found in an east drift. Before this could be removed the tunnel caved and has not been opened since.

Lexington-Argenta Workings. These workings are the site of the first discovery of ore in the district. They are located from 100 to 500 feet below the Midway tunnel and 2,000 feet to the west. The Argenta workings consist of three tunnels driven along a vertical break in the Phelan limestone. At present, they are largely inaccessible. A little stoping appears to have been done in the lowest of the tunnels and a small amount of ore may have been extracted. The ore appears to be in the form of small pockets in the limestone. These mines have not been worked for more than 30 years.

The Lexington group, on the south side of Lexington Canyon, consists of a few short tunnels driven southward through the Phelan limestone to the contact with the lower porphyry. These tunnels are all caved at the present time and information as to the nature of the underground workings was not available. Ore which could certainly be considered to have come from these workings was not found.

Dolly Clark Mine. The Dolly Clark mine is the westernmost mine in the district. It consists of a tunnel 600 feet long driven just below the contact of the lower porphyry with the Phelan limestone into the Wardlaw shale. Several short drifts and winzes have been driven off the main tunnel in quest of ore, but up to the time of the writer's last visit to the mine, no appreciable values had been discovered. The mine has been shut down since 1937.

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MT. VERNON, ILLINOIS,
May 11, 1942.

